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L. O. HOWARD, Chief

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SOLID-STREAM SPRAYING AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH IN NEW ENGLAND.

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INTRODUCTION.

In nearly all parts of the United States damage is produced each year by leaf-eating insects, and the application of arsenicals, in the form of poison sprays, has been demonstrated to be the most efficient method of suppression or control. In the work of suppressing and preventing the spread of the gipsy moth and the brown-tail moth, spraying with arsenate of lead on an extensive scale has proved a very important factor. The magnitude of the insect problem which the ravages of the gipsy moth has developed in the New England States made it necessary to devise extensive improvements in insecticides and spraying machinery.

HISTORY.

When the work against the gipsy moth was first undertaken by the Commonwealth of Massachusetts, the problem was one of extermination rather than repression, and spraying with arsenical

poisons at that time was not regarded as an important factor. The State Board of Agriculture of Massachusetts later conducted experiments with insecticides which resulted in 1894 in the development of arsenate of lead as the most economical and effective poison for control work against leaf-eating insects. After these demonstrations, spraying became more general, owing to resulting effectiveness as well as to a considerable reduction in expense, and this naturally led to the modification and improvement of machinery and apparatus for applying mist sprays.

In 1895 the late J. A. Pettigrew, while superintendent of Prospect Park, Brooklyn, N. Y., began solid-stream spraying, and in the Yearbook of the United States Department of Agriculture for 1896 there appears an article by Dr. L. O. Howard on the subject. The sprayer assembled by Mr. Pettigrew had steam as its motive power, the pump and engine being connected to a watering cart. (Pl. II.)

Owing to the discontinuance of appropriations by the Legislature of Massachusetts, the gipsy-moth work was stopped in 1900, and no State work was carried on in combating this pest until May, 1905, when a further appropriation was made.

In 1905 the late Gen. S. C. Lawrence, of Medford, who was intensely interested in the work of combating the gipsy moth on his large estate and others surrounding it, saw the necessity of larger machines for spraying and purchased a high-power machine which was operated by an air-cooled gasoline engine and had a triplex cast-iron pump. This machine did very good work, but its use indicated that further improvements were desirable.

Through the efforts of the writer, while in the employ of the State of Massachusetts, some important mechanical devices in solid-stream spraying were constructed, and during the last few years, while carrying on the scouting and extermination work for the Bureau of Entomology, United States Department of Agriculture, further improvements have been made. Many of these improvements are now being extensively used in New England, but in order that others contemplating the use of such apparatus may know the most economical and practical methods the following suggestions, illustrations, and tables are submitted.

After a careful inspection of the territory surrounding the known infested area in Massachusetts, it was found that it had increased from 359 square miles in 1900 to 2,500 square miles in 1905. It was apparent that a considerable amount of spraying must be done, but the apparatus available for so large an operation was insufficient and indequate, there being hardly any spraying machinery on the market except that principally used for orchard spraying. After the first season's work efforts were made to improve spraying machinery, so that the work could be brought to a higher degree of

efficiency. Our efforts led to the construction of a high-power solid-stream machine, which was an improvement over those used in the previous season. These machines were assembled from stock parts purchased in the open market and consisted of stationary engine, with battery ignition and single cylinder or duplex pump.

While the results accomplished were an improvement, they were not satisfactory as the pump did not furnish a steady pressure and the engine caused too much vibration. In 1907 a two-cylinder marine engine and triplex cast-iron pump were used. This machine was an improvement over the first, but the pump would not stand high pressure and its use resulted in a large amount of valve trouble. Later a four-cylinder marine engine was used with high-tension magneto and a triplex pump made of phosphor-bronze having metal valves. This proved satisfactory, and practically the same outfit is in use to-day.

DESCRIPTION OF APPARATUS.

The high-power solid-stream sprayers being used by the Bureau of Entomology are assembled as follows (Pl. III):

Caravan running-gear, U-shaped tank, phosphor-bronze pump, 14-horsepower marine engine. Running gear built of best oak stock with high-grade iron. Wide tires on wheels, cut-under front wheels, with springs all around, fitted for a two-horse hitch. Tank made from select pine stock, capacity of at least 400 gallons, with a solid roof capable of carrying supplies on the top. An arch made of heavy steel straps is bolted on the inside to protect the agitator. This arrangement provides space in the tank for storing the hose while the sprayer is being moved from place to place and eliminates the need of a supply wagon, reducing the cost of operation about $5 a day. The roof extends over the engine, and side curtains are used to protect it from weather. Pump, triplex type, with cylinders, valves, valve chambers, and plungers made of a high-grade phosphor-bronze with a tensile strength of 35,000 pounds per square inch. This makes a much lighter and more compact pump than would be safe if cast iron was used, as the latter rarely has a tensile strength of more than 15,000 pounds per square inch. The cylinders and displacement chambers are cylindrical in design, so as to offer no flat surfaces to pressures; thus greater strength can be secured with the same amount of metal. The valves and waterways are extra large to permit high speed while filling. The valve chambers are so designed that any one valve may be removed without disturbing another. The uprights are made of high grade iron with babbitted bearings. The crank is a drop-forging which usually has an elastic limit of over 74,000 pounds per square inch and is not subject to crystallization. Cast-iron cranks should be avoided, as they usually have an elastic limit

not exceeding 40,000 pounds. The pump is attached to the engine by a durable clutch, with gear and pinion. Connected with the pump are two automatic safety release valves, one set at 300 pounds and the other at 350 pounds. By having two release valves a variation of pressure can be obtained from 275 pounds to 375 pounds without making any change in the release valve and not running the engine at an excessive rate of speed. These valves are properly set and should not be adjusted in the field.

THE ENGINE.

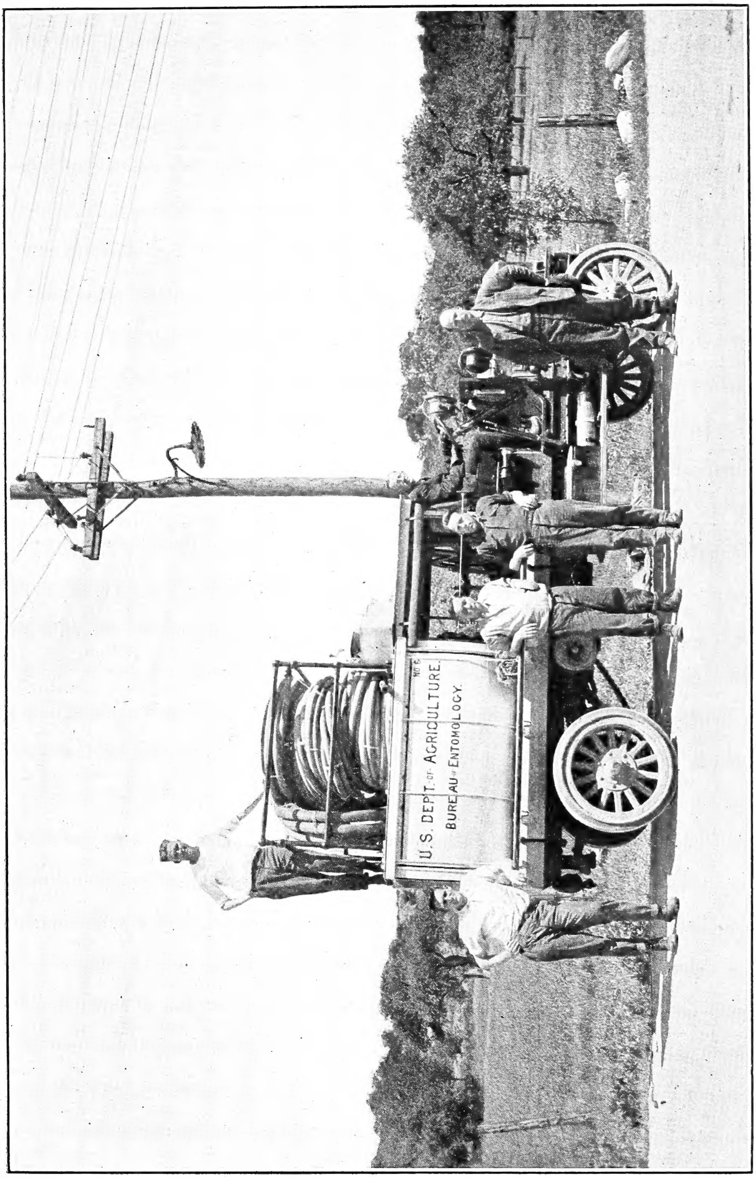
The engine is a 4-cycle, water-cooled type, having four cylinders, with a maximum of 14 horsepower, and is equipped with a high-tension magneto, and so oiled as to require little attention from the engineer. The cooling system consists of a coil of pipe submerged in the spray tank and fed by a supply tank located near the engine. The gasoline tank has a capacity of 10 gallons. The agitator consists of three long paddle blades extending the entire length of the tank and has proven more satisfactory than single propeller blades.

The safety or release valve is so arranged on the delivery line that the solution is automatically released into the spray tank whenever the nozzles are shut off. The piping, wherever subjected to high pressures, is extra heavy, with double-strength fittings, and is so arranged on the pressure side that the solution may be delivered into the hose for spraying or diverted into the tank when filling. The suction line is arranged so that the solution may be drawn directly from the tank or water from the suction hose when the tank is being filled.

While this arrangement is not essential in spraying work, it enables this apparatus to be used for other purposes, such as fighting fires, etc.

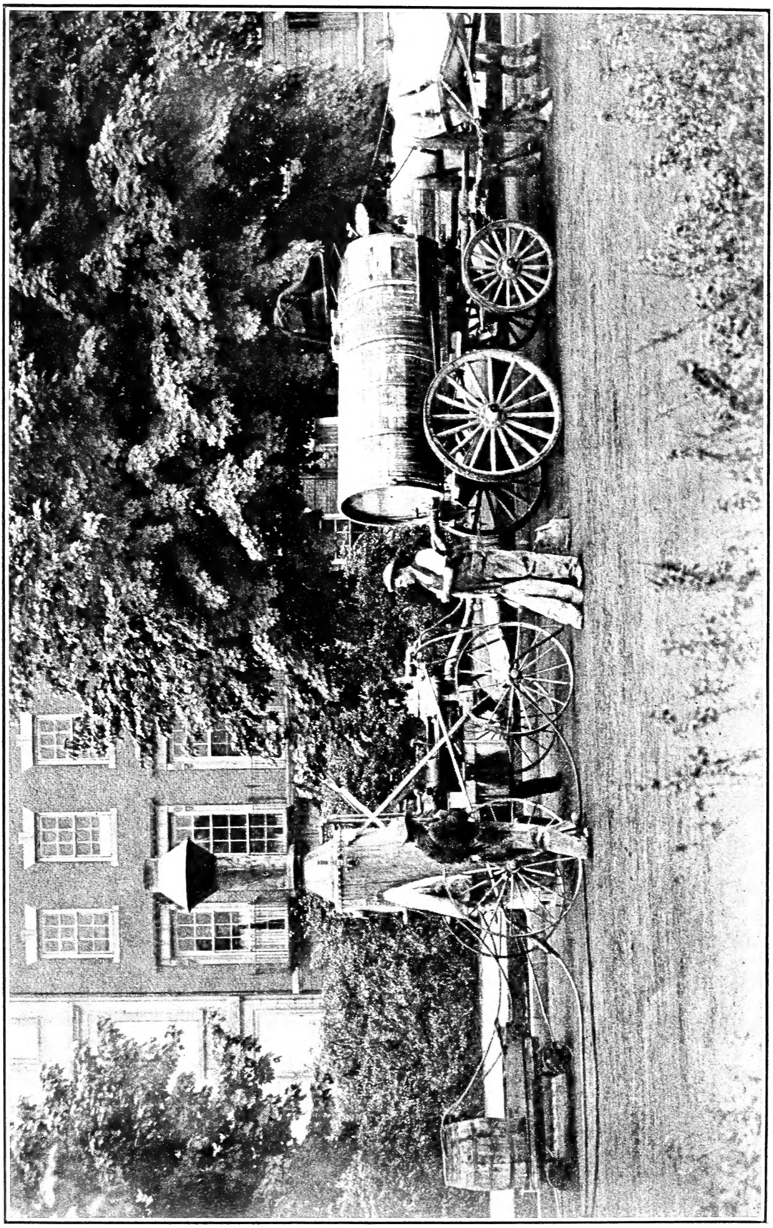
THE HOSE.

Hose used in high-power solid-stream spraying should be constructed to stand a working pressure of 600 pounds, with couplings especially adapted for high-power work. Hose used in this work not only has to stand high pressures, but is also subject to severe strain in pulling and hauling that is necessary especially in woodland spraying. Unless a very high grade 10-ply hose is used, with heavy inner tube and outer walls, it is advisable to have 7 or 8 ply hose covered with a cotton jacket treated to prevent mildew and increase wearing quality. It is also advisable to use high-grade hose, whether covered or not, as the life of it will be so extended as to reduce the yearly cost to a considerable extent. Couplings should be constructed so as to make it impossible for them to blow off under pressure and to offer as little resistance as possible when the hose is being pulled. In woodland spraying parts protruding from cou-



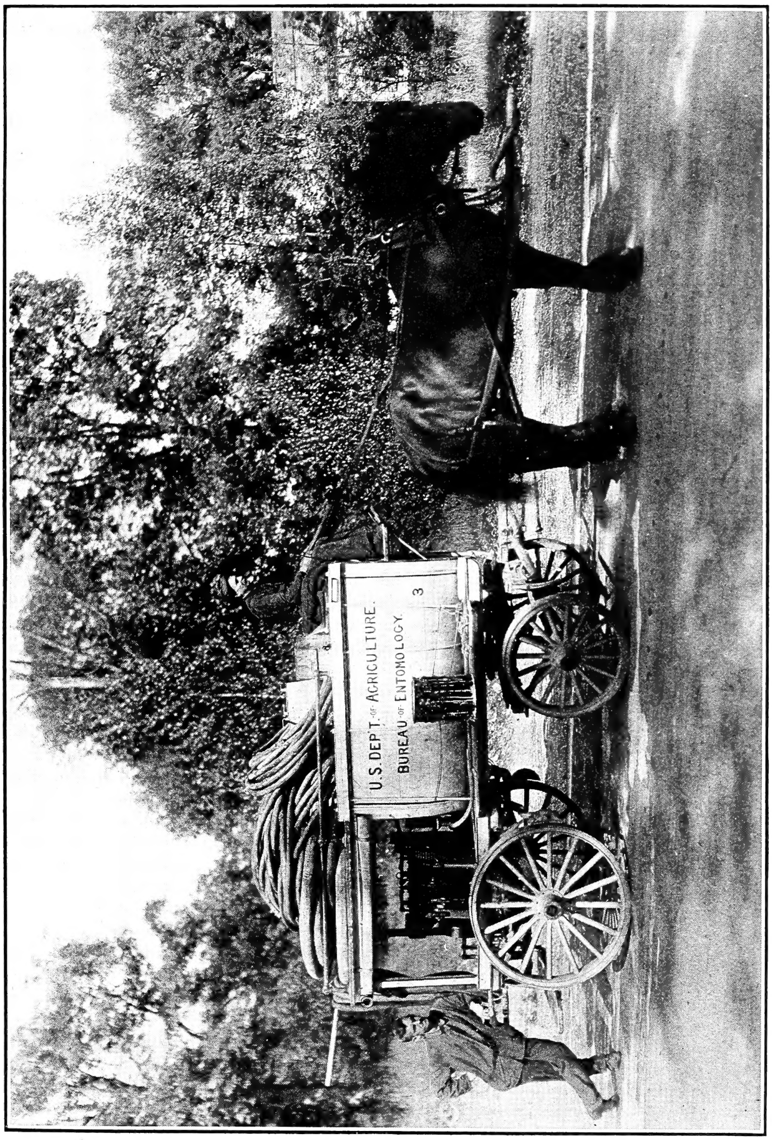
SPRAYING AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

Motor-truck sprayer of the Bureau of Entomology with crew and equipment. (Original.)



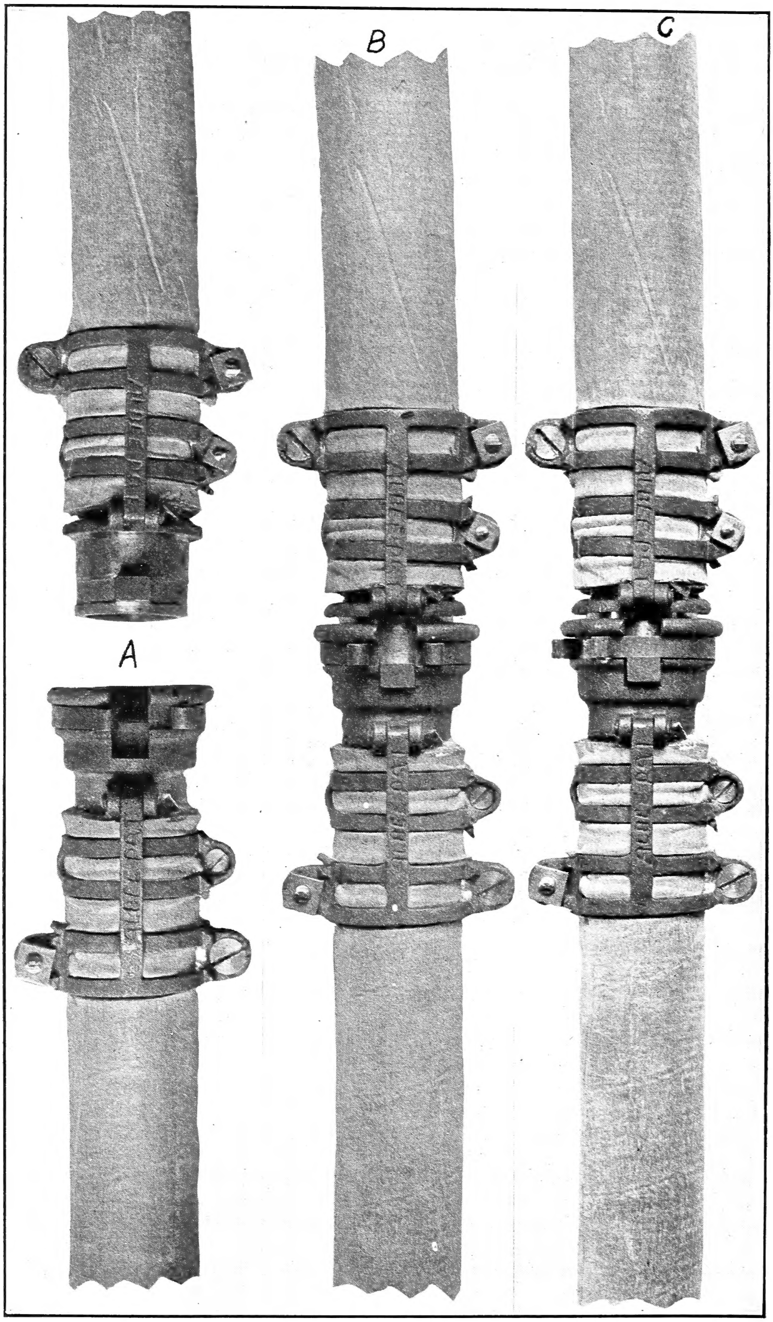
AN OLD TYPE SOLID-STREAM SPRAYER.

Sprayer built by Mr. J. A. Pettigrew and used in the Boston parks in 1907. (Original.)



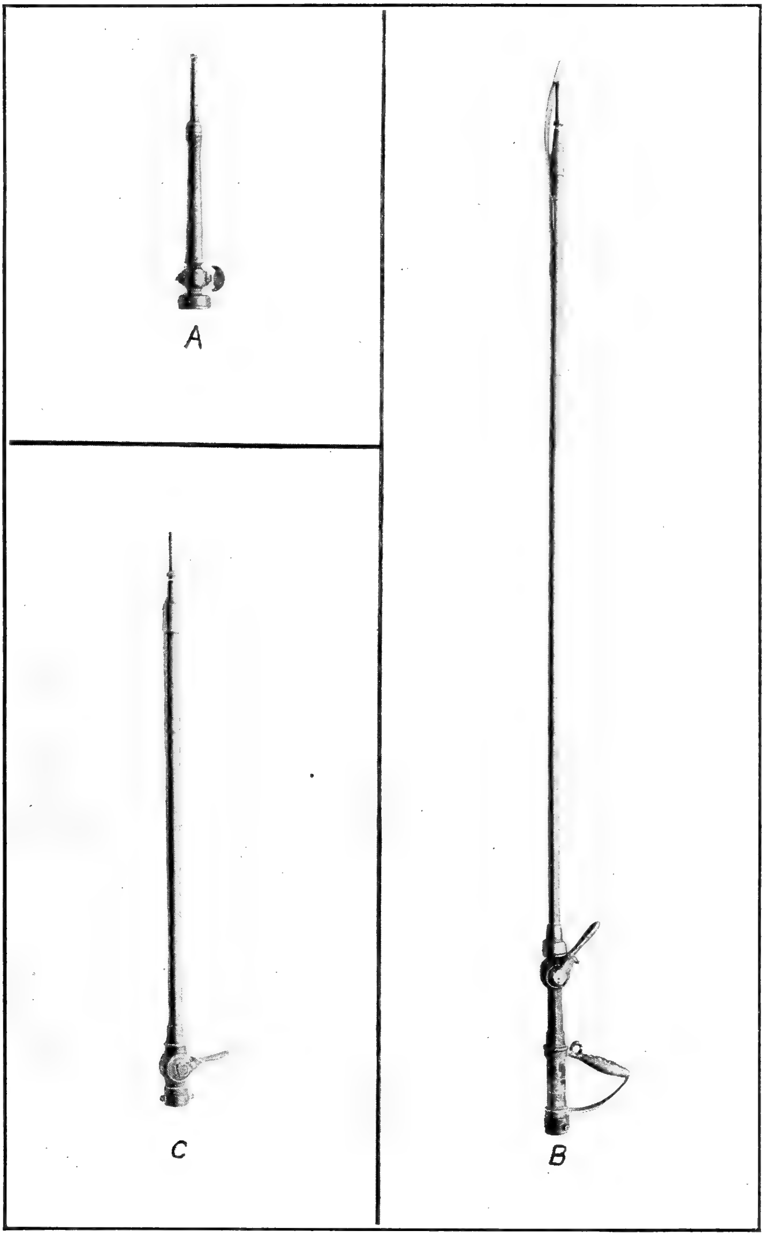
THE SPRAYING OUTFIT IN USE TO-DAY.

Present type of horse-drawn high-power solid-stream sprayer with equipment. (Original.)



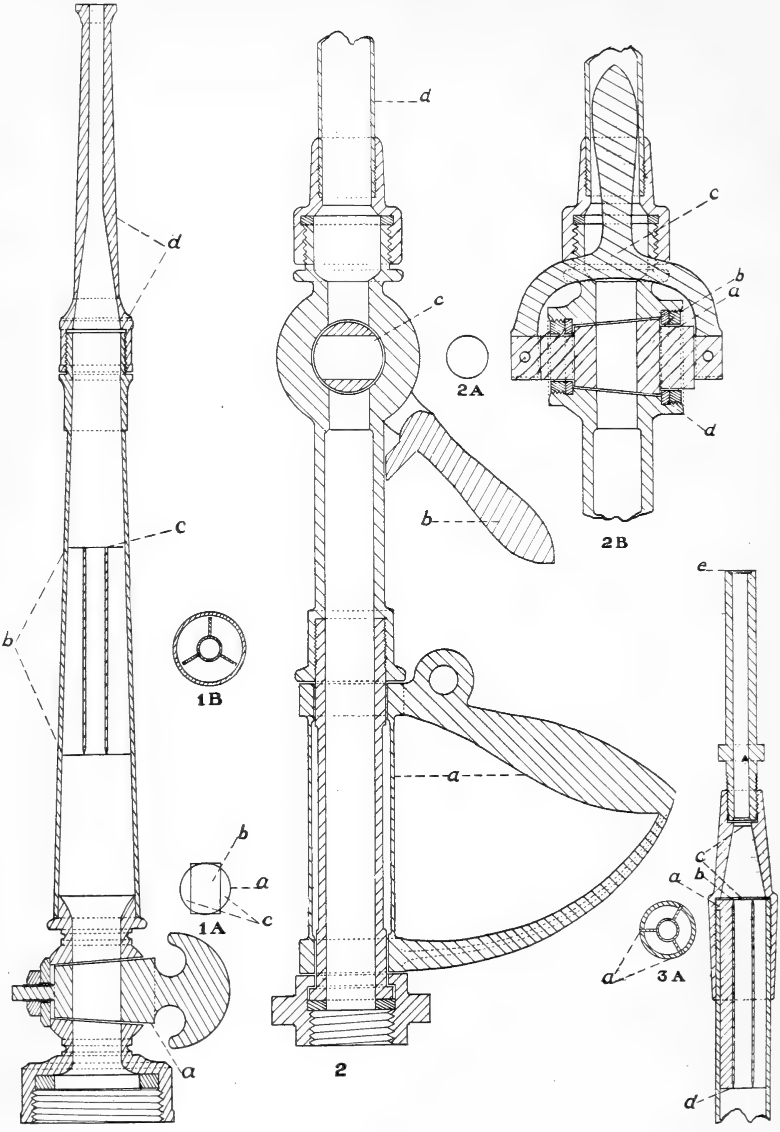
A NEW FEATURE IN HOSE COUPLINGS.

High-power hose equipped with quick-hitch couplings. A, Uncoupled; B, coupled but not fastened; C, coupled and fastened. (Original.)



COMPARISON OF OLD AND NEW TYPE NOZZLES.

Nozzles for solid-stream sprayer. A, Old type nozzle; B, latest type, known as the Worthley nozzle, with spreader; C, smaller size, same type as B. (Original.)



COMPARISON OF DETAILS OF THE OLD AND THE IMPROVED TYPES OF NOZZLES.

FIG. 1.—Old type nozzle. *a*, Shut-off open; *b*, Hopkins; *c*, square top of Hopkins; *d*, taper at base of tip. FIG. 1A.—Square waterway in shut-off; *a*, opening of pipe above and below shut-off; *b*, rectangular opening in shut-off; *c*, protruding shoulder in shut-off when open. FIG. 1B.—Cross section of tube and Hopkins, showing Hopkins loose in the chamber of the nozzle.

FIG. 2.—Base of Worthley nozzle. *a*, Swivel handle; *b*, shut-off handle; *c*, shut-off closed; *d*, base of tube of nozzle. FIG. 2A.—Clear waterway in shut-off when open. FIG. 2B.—Details of the shut-off; *a*, shut-off open; *b*, nut; *c*, shut-off handle; *d*, washer.

FIG. 3.—Tip of Worthley nozzle. *a*, Method of holding Hopkins in position in top of tube; *b*, top of Hopkins leveled to sharp edge; *c*, condensing head in end of tube; *d*, beveled base of Hopkins; *e*, protecting shoulder. FIG. 3A.—Cross section of tube and Hopkins. *a*, Hopkins firmly held in place at top of tube. (Original.)

plings are a great hindrance to the work, as they become entangled in twigs, rocks, and other obstructions. Recently there has been placed on the market a quick-hitch coupling that is easily connected without the use of wrenches and is being used by this Bureau in its spraying work. It promises a great saving in time when long lines of hose are being used. (Pl. IV.)

NOZZLES.

From observations made by the writer on solid-stream spraying operations in 1907, 1908, and 1909 it was evident that the nozzles being used were not giving satisfaction and that some improvement should be made. The nozzle then in use had a long, tapering tube with the shut-off near the tip or at the base and was constructed so as to offer considerable resistance to pressure. (Pl. V, *a*.) The "hopkins" (a finlike arrangement used in open-bored nozzles to stop the circular movement) was placed near the hose end and the tips were tapered nearly to the end, which caused the stream to spread, by reflex action, immediately after leaving the tip. Water passing through lines of hose takes a spiral motion, owing to the spiral winding in the manufacture of the hose.

Experiments were conducted in 1909 and 1910 for the improvement of solid-stream nozzles, and resulted in the production of a nozzle that gave much more satisfaction, gaining at least 25 feet in the height of the stream, working at the same pressure, with the same size tip, and using the same amount of solution. Later it was observed that some means should be devised for breaking the force of the stream, so that small trees and the lower foliage of large trees could be properly sprayed. For this purpose a strip of brass, slightly curved, about 10 inches long and 1¼ inches wide, known as a spreader, was attached to a brass ferrule about a foot in length, so that it could be moved up and down the tube of the nozzle. When this brass strip is slid beyond the tip the force of the solution coming in contact with it is broken up into a fan-shaped stream, thus giving a good mist spray. (Pl. V, *b*, *c*.)

Solid-stream nozzles now being used have a full-way shut-off at the hose end which is packed on both sides to prevent leakage, and a reduction is made in the condensing head for a tapered way of approximately 1 inch in length. The "hopkins" is placed directly in the end of the tube, straightening the stream practically at the tip entrance. The tips are all bored from solid metal, making an absolutely smooth waterway. A swiveled handle is provided on the large nozzles to permit them to turn freely when the hose twists, without annoyance to the nozzleman. The introduction of this nozzle practically eliminated the climbing of forest trees in spraying. For full details of construction, see Plate VI.

MOTOR-TRUCK SPRAYER.[1]

The first motor-truck sprayer used in New England was built in the winter of 1910 along lines suggested by the writer. This sprayer was used by the State of Massachusetts and gave such satisfactory results that several others have been built and are being used in that State. (Pl. I.)

In the fall of 1915 a machine of this type was built for the Bureau of Entomology and has been used to great advantage during the past summer.

Profiting by the experience secured when the other machines were constructed, the one built for the Bureau was improved and perfected in many respects, so as to render its operation more perfect and economical. A machine of this type is particularly useful where work has to be done in locations demanding the use of long lines of hose and where water must be hauled long distances. It can accomplish more work in a single season than four horse-drawn high-power sprayers and can be operated more economically on account of saving time on the road and reduction in the number of men needed.

One and one-eighth inch hose is used on this machine, as it does not offer as much resistance as the hose of smaller diameter, and makes it possible to maintain proper pressures at the nozzle when 2,500 feet of hose is required. Two automatic safety release valves are connected to the pump, one set at 300 pounds and one at 500 pounds. The maximum pressure needed on 2,500 feet of $1\frac{1}{8}$-inch hose to obtain 225 pounds at the nozzle is 475 pounds, against approximately 600 pounds in the case of 1-inch hose.

When 1-inch hose is used the pressure must be increased 50 pounds for every 100 feet that the nozzle is operated above the level of the sprayer. With $1\frac{1}{8}$-inch hose a slightly greater pressure is required. This matter must be given careful attention when lines of hose are run to hilltop areas which are at much greater elevations than the sprayer.

When the sprayer truck combination is not in use the pump and tank attachment can be easily removed and a commercial body attached which can be used in transporting supplies to and from the field. (Pl. VII.)

The construction of the motor-truck sprayer is of special design, owing to the double work which it is called upon to perform. As the truck must propel itself and at the same time maintain high

[1] Since this manuscript was prepared a more powerful truck sprayer has been designed. For this purpose a 5-ton truck with a worm drive and a pump of greater capacity has been used. This outfit is to be used in difficult spraying work in the border territory of the gipsy moth infested region.

pressure for spraying, it is necessary to have an engine transmission of extra strength, and many other parts are oversize from what would be necessary for an ordinary 3-ton truck. The chassis is of 1-inch beam construction, with platform springs and chain drive. The engine is 45–60 horsepower and has an internal governor. It has three speeds forward and one reverse, with special transfer arrangement to the pump which makes it possible to spray while traveling or standing. The controls for operating either the truck or spraying attachment are easily reached from the driver's seat. The pump is practically the same as those on horse-drawn outfits, with the exception that it is reinforced in many places to stand extra high pressures. The tank is of the U-shaped type, with a 400-gallon capacity.

In doing street-tree or roadside spraying, the motor truck is especially adapted, as very little time is wasted in securing water.

POISON.

The amount of poison to be used varies with different insects, as some species will withstand more than others. In the case of the apple-tree tent caterpillar (*Malacosoma americana* Fab.) about one-half the amount of poison is required that is necessary to kill the gipsy-moth caterpillars. It is obviously wasteful to use an unnecessary amount of poison. In the case of the gipsy moth, 10 pounds of arsenate of lead and 100 gallons of water is sufficient until the caterpillars have passed the third stage; then the poison should be increased to 12½ pounds to 100 gallons of water. This increase is necessary, as the caterpillars are more resistant to poison as they grow older.

Spraying against any leaf-eating larva at the time when it is about to change to the pupal stage is not as a rule satsifactory, as very little feeding is done for a few days previous to transforming.

In purchasing arsenate of lead paste, the following specifications have been found satisfactory:

Fifty per cent actual dry arsenate of lead, not less than 15 per cent arsenic oxid (As_2O_5), not more than three-fourths of 1 per cent of soluble arsenates, no free acids, no adulterant or inert substances. Arsenate of lead should be in a good mechanical and physical condition and should be subjected to analysis.

These specifications carry 3 per cent more arsenic oxide (As_2O_5) than is required by Federal law, but much better work is done than by the weaker percentage and with more economy.

Poison carried over from one season to another in wooden containers should be tested before it is used to ascertain if it contains

the proper amount of moisture, otherwise a larger amount of actual arsenate of lead may be used than is necessary.

Dry arsenate of lead has been tried on a small scale and has given good results. It has not been used extensively, as it is more expensive than the paste form.

MIXING POISON.

Arsenate of lead in paste form can be obtained in different-size steel drums or wooden packages, and should contain 50 per cent water. The lead, being heavier than the water, readily settles at the bottom of the container and should be stirred to an even consistency before being mixed with water for spraying. If this is not properly done an uneven strength of the solution is the result and consequently spraying operations are often unsatisfactory. This is one of the parts of a spraying operation that is easiest to neglect, and in order to secure an even solution a mixer has been devised, as shown in Plate VIII. It can be attached to a 100-pound drum of arsenate of lead and the contents brought to an even consistency in from 3 to 5 minutes. The lead should be poured into another drum to make sure it is thoroughly mixed, thus increasing its efficiency and lessening the cost of labor.

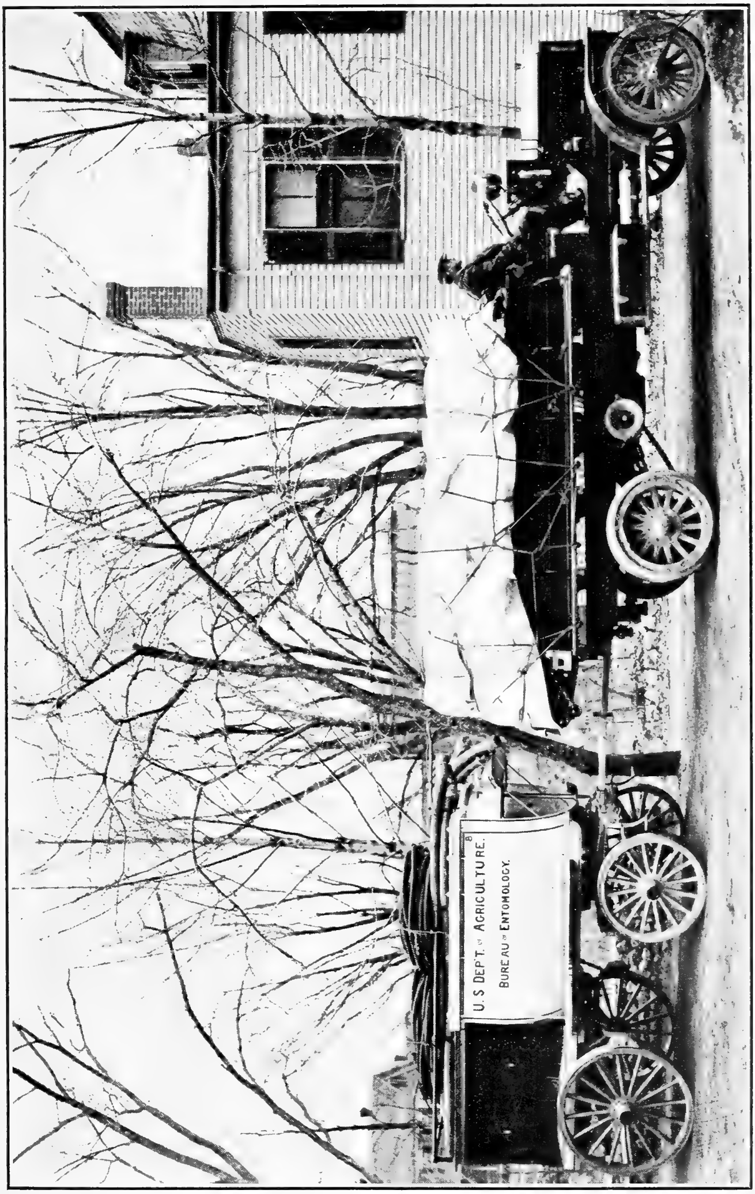
AGITATION.

Agitation is one of the most important factors in the operation of any spraying machine, owing to the fact that if constant and thorough agitation is not maintained uneven results may be expected. In some power machines the agitator is in motion only when the pump is working, but this is not a satisfactory arrangement. If the machine is moved from one location to another and the pump is stopped a large part of the poison will settle to the bottom of the tank. It is very difficult to get arsenate of lead again into suspension, under such conditions, as it has to be sucked gradually from the bottom of the tank by the agitator, which will not function as well as if the poison is not allowed to settle.

On all machines the agitator should be directly connected with the engine and when the pump is not in use the engine should be run slowly, so as to keep the solution well mixed until the tank is empty.

AMOUNT OF SOLUTION TO BE USED.

The amount of solution used in solid-stream spraying should be carefully guarded, as it is very easy for considerable waste to occur. With high-power outfits using 1-inch hose and one-fourth-inch tip on the nozzle, from 25 to 35 gallons of solution is being delivered



THE MOTOR TRUCK AND PRESENT-DAY METHODS.

Motor truck used for hauling supplies and spraying outfit. Total load, four tons.

AN IMPROVED TYPE OF POISON MIXER.

Poison mixer attached to 100-pound drum, showing paddles.

every minute, and as the average shade tree contains about 3,000 square feet of foliage and $9\frac{1}{2}$ gallons of solution will actually cover this amount of foliage, it is practically impossible to prevent a small amount of waste, although a much smaller percentage than would be supposed results if care is taken by the nozzleman. One-half minute of solid-stream spraying at the proper pressure will ordinarily spray the average shade tree.

There are several conditions which would cause this estimate to vary, such as high winds, location of tree, etc. In directing solid-stream spray, the force of the stream should never be allowed to strike the foliage, as the solution will not adhere, but is driven off. It should be applied in as near a mist form as possible. In the spraying of shade trees care should be taken to direct the stream so that the mist will blow or drift through the foliage. It is not always possible to spray all sides of a tree, but it can usually be completely sprayed by drifting it through or by allowing the stream to go over the tree. In spraying trees on country roadsides, where the water supply is not always easy of access, considerable time can be saved by filling the tank when there is an opportunity, even if it is not empty. If this is done an accurate method should be worked out to determine the amount of water to be added so that the proper weight of poison can be placed in the tank. Considerable time is required to secure water, even if hydrants are available.

PRESSURES.

A knowledge of the correct pressures to use in solid-stream spraying is most essential. As has been previously stated, the solution should reach the leaves as a mist if best results are to be obtained. If this is not done much poison is wasted, and if the force of the stream is allowed to come in direct contact with the foliage it often tears and damages the leaves.

After several years experience and many experiments, it has been concluded that to obtain the best results the pressure at the nozzle when 1-inch hose is used with any sized tip should be 225 pounds in order to break the stream into a mist at the proper place.

It has been determined by tests shown in Table I that it is not practical to use over 1,500 feet of 1-inch hose with the high-power machine when a one-fourth-inch tip is used, and not over 600 feet of 1-inch hose when a five-sixteenths-inch tip is used.

TABLE I.—*Correct nozzle pressures for different lengths of hose and sizes of tips.*

Length of hose.	Nozzle pressure.	Pressure at the machine.			
		One-eighth inch.	Three-sixteenths inch.	One-fourth inch.	Five-sixteenths inch.
Feet.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
100	225	225	225	240	250
200	225	225	225+	250	275
300	225	225	230	260+	300
400	225	225	240−	275+	325
500	225	225	250−	290−	350
600	225	225	250	305−	400−
700	225	230	255	310+	....
800	225	230+	260	320	....
900	225	235	265	330	....
1,000	225	235+	268	340	....
1,100	225	240−	270	350	....
1,200	225	240	272	360	....
1,300	225	240+	275	370+	....
1,400	225	240+	278	390−	....
1,500	225	245−	280	410	....

The tables submitted are actual readings taken in the field, and the nearest to a 5-pound point was taken. Some of the variations can only be explained by the expansion of the rubber hose, which also explains the difference from the friction loss in 1-inch iron pipe.[1]

EXPERIMENT TO DETERMINE THE DISTRIBUTION OF POISON ON FOLIAGE.

In order to determine how thoroughly trees were being sprayed by using the solid-stream method a number of experiments were conducted during the summer of 1916.

For this purpose a series of ferrotype plates, 14 by 10 inches, were secured and treated with black coach paint so that any spray coming in contact with them could be seen. The plates were numbered and attached to bamboo poles about 12 feet in length. This was done by splitting the small end of the pole, and after inserting the plate it was sewed in place securely with copper wire.

The plates were then placed in different positions and at different heights in trees that were to be sprayed and a record secured of the effectiveness of the work. (Pl. IX.) This is a method that can be used by anyone to test the thoroughness of spraying for leaf-eating insects.

One test was conducted to determine the time required properly to spray a shade tree when the solid-stream method is used. The tree selected was 65 feet in height, and excellent results were secured by applying the spray for half a minute. A glance at Plates X and XI shows the thoroughness of the treatment in this test and illustrates the value of this method of spraying when properly used.

[1] See Engineering Work in Towns and Small Cities, by Ernest McCullough, 1906, p. 359. Pumping Machinery, by William M. Barr, 1908, p. 108.

SHADE-TREE SPRAYING.

The spraying of shade trees with arsenate of lead should be accomplished at as early a date as possible after the foliage has sufficiently developed. (Pl. XII.) Early spraying not only applies to the gipsy moth, but will poison many brown-tail caterpillars, as they are much earlier feeders than the gipsy moth. In the case of the elm leaf-beetle (*Galerucella luteola* Müll.) much is accomplished in poisoning the adult beetles, which do a small amount of feeding after coming out of hibernation before mating and laying eggs, as they are very easily poisoned at that time. It is often argued that solid-stream spraying on street trees is too expensive and that the work can be done much cheaper with smaller apparatus. The principal reason for this is because of the low first cost of the smaller outfits. (Pl. XIII.) This may be true for a single year, but for two or more years the solid-stream method is the cheaper. The total cost of the most expensive high-power apparatus on the market at the present time is approximately $1,500 for a complete equipment. It is safe to figure depreciation at the rate of 20 per cent each year, although there are machines in the field at the present time that have been used 8 years and have only required an annual overhauling and the replacement of small worn parts. In 20 days' spraying one large machine should treat 10,000 shade trees. This would average only 3 cents for each tree in depreciation which is not prohibitive to any municipality. Taking everything into consideration, the entire cost of spraying shade trees with the solid stream does not exceed 12 cents per tree if the work is managed properly. The following figures are submitted to show how the cost per day is computed for 20 working days:

1 pair of horses and driver	$6.00
3 men, 8 hours each	7.50
560 pounds of poison, at 5 cents per pound	28.00
10 gallons of gasoline	1.80
1 gallon of oil	.30
Depreciation per day at 20 per cent per year	15.00
	$58.60

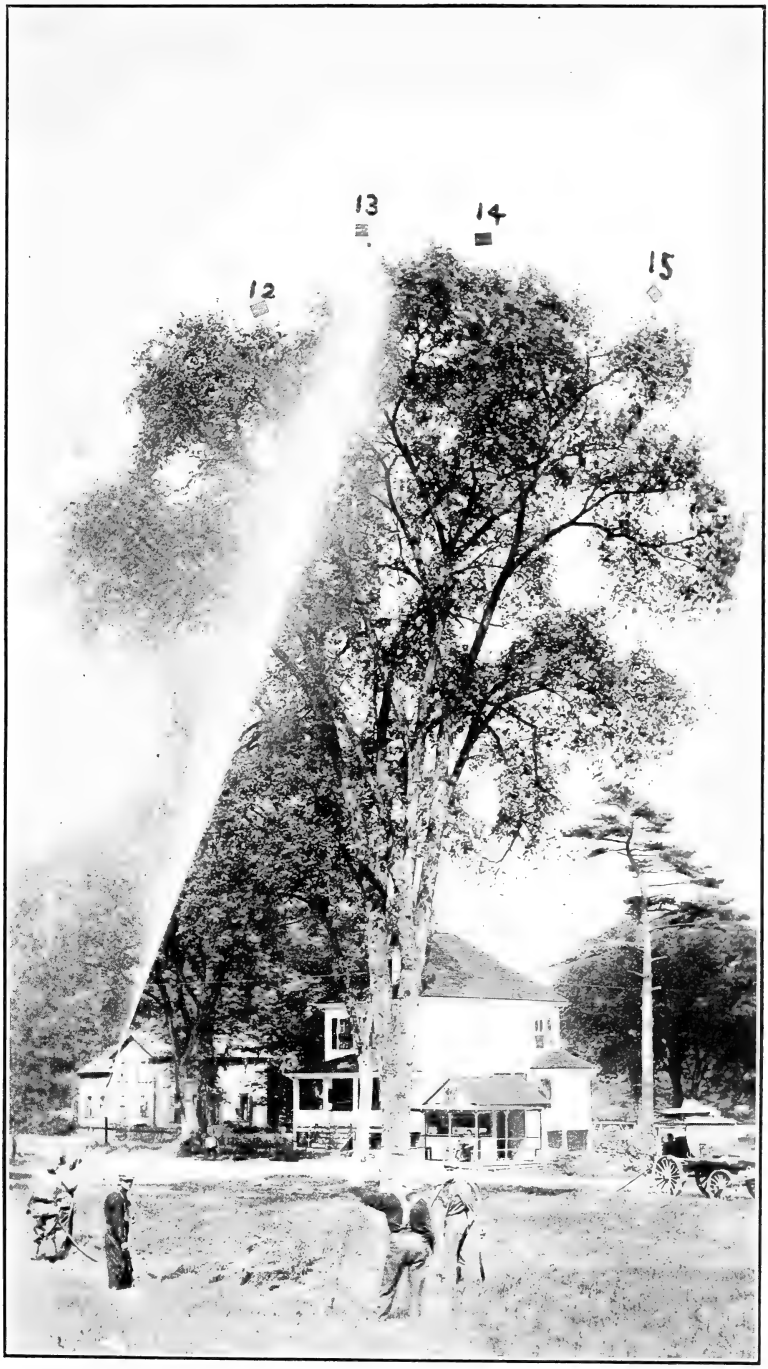
The average number of shade trees sprayed with each 400 gallons of poison is 35, and 14 tanks (5,600 gallons) in 8 hours is a good average, totaling 490 street trees per day, making the average cost per tree about 11¾ cents. In treating shade trees, where any considerable amount of spraying is to be done, the use of small outfits in mist spraying is much more expensive than the solid-stream method. In an experiment conducted during the summer of 1916 the cost of treatment with a small hand outfit was more than twice the amount per tree that it was when the solid stream was used. While one can

find considerable variation in the cost of applying the mist spray, either with gasoline or hand outfits, it is more than double the cost of solid-stream spraying, which, in the long run of the season's work, will equal an amount that will more than two-thirds pay for a high-grade solid-stream machine and equipment. By following the mist method for two seasons a high-grade outfit has practically been thrown away and with no asset shown for money expended.

WOODLAND SPRAYING.

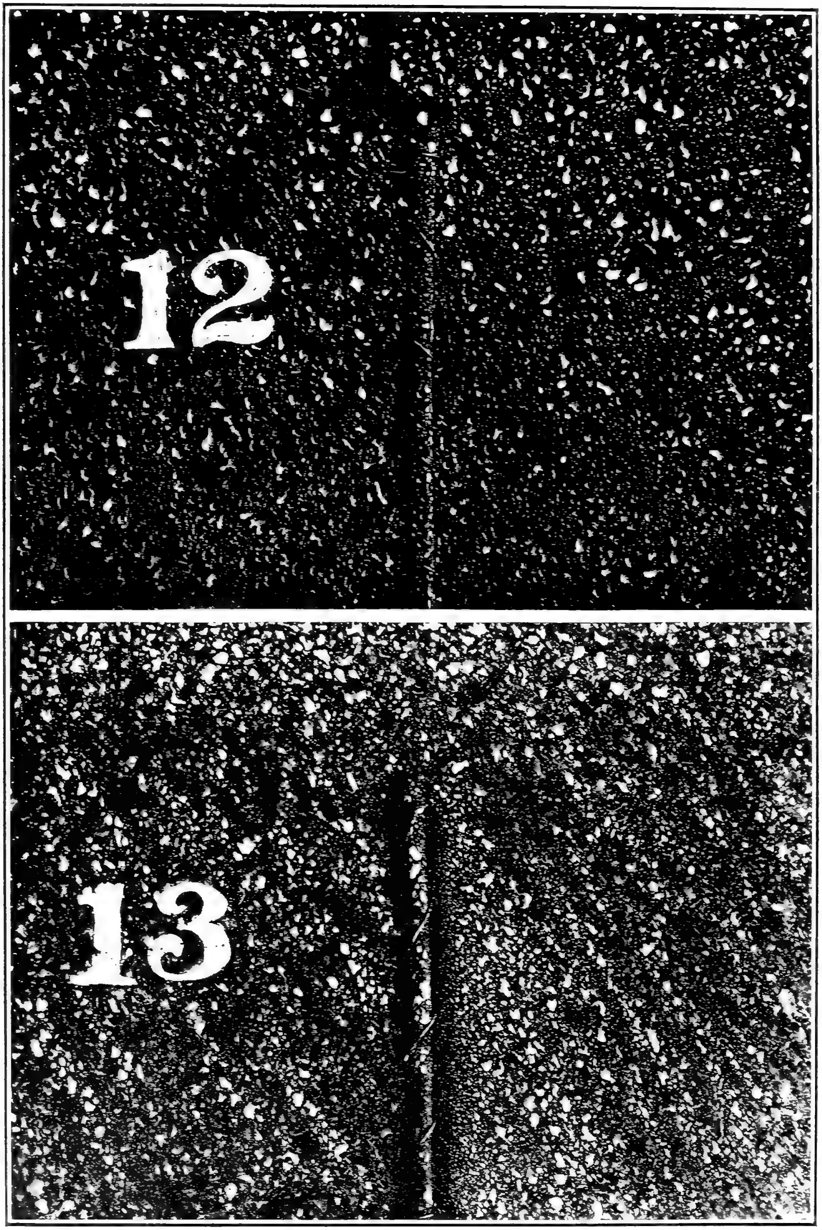
In woodland or park spraying the solid-stream method is in a class by itself, as the climbing of trees over large areas makes the mist method not only too slow but laborious and expensive. With a high-grade solid-stream machine properly equipped an average of from 12 to 15 acres can be sprayed in a day. This applies to large areas where machines can be operated without the necessity of moving any great distance in the day's work. Twenty-one acres of woodland, consisting mostly of trees 60 to 70 feet high, is the maximum treated in a single day. (Pl. XIV.) In this instance the water supply was convenient and easily accessible. The solid-stream machine for woodland spraying should be equipped with from 1,000 to 1,500 feet of 1-inch hose; 100 feet of $2\frac{1}{2}$-inch suction hose, suction strainer, two nozzles (one long and one short), and with each nozzle one of the following tips: $\frac{5}{16}$, $\frac{1}{4}$, $\frac{3}{16}$, $\frac{1}{8}$ inch bores. The nozzles should be equipped with a brass spreader for spraying undergrowth and low foliage. (Pl. XV.) Hose should be provided with couplings that will not blow out—if expensive delays are to be avoided. Spraying in woodland should be arranged so that whenever possible the location of the hose may be changed while the sprayer is being filled. Much time will be lost if this is not done, and 10 men are usually necessary where long lines of hose are being used.

Men should be so located on hose lines that the nozzlemen will not be hindered by the weight of hose. The number of men needed in woodland spraying is determined entirely by the lengths of hose used. One hundred feet of 1-inch 8-ply cotton-covered hose weighs 84 pounds, and carries 4.8 gallons of water weighing 32.64 pounds, making the total weight when spraying 116.64 pounds. This makes it necessary to assign a man to every 100 feet, besides the nozzleman. The cost of woodland spraying where large areas are involved averages about $5.50 per acre. Where only small areas are sprayed the cost is much greater. Six hundred gallons of solution, when properly applied, will usually spray an acre and no climbing should be necessary. In experiments recently conducted, a pine tree $99\frac{1}{2}$ feet high was successfully sprayed from the ground. Good results can usually be obtained in woodland spraying by directing the stream through the open places in the foliage in order to minimize damage



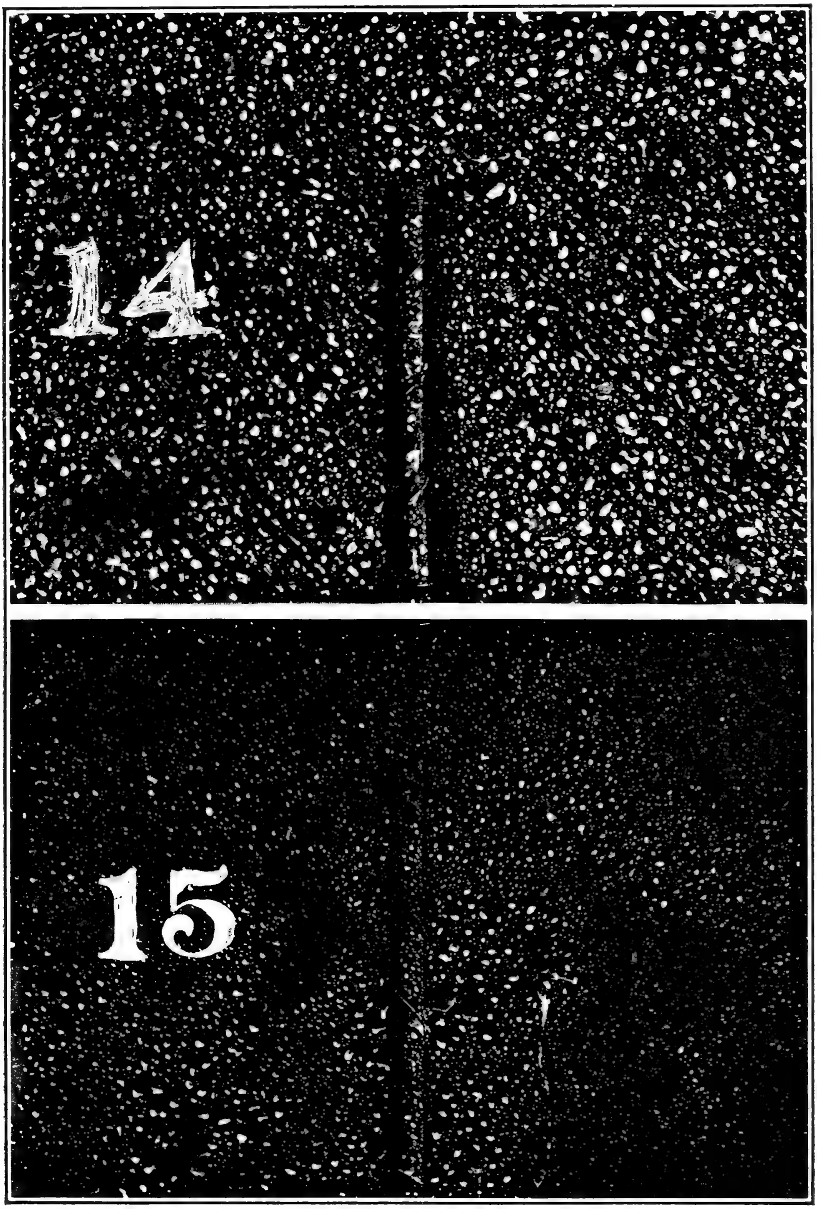
TESTING THE DISTRIBUTION OF POISON SPRAY.

Spraying elm tree 65 feet high with solid stream. Note the plates at top of tree which were used to secure a record of the distribution of the poison. (Original.)



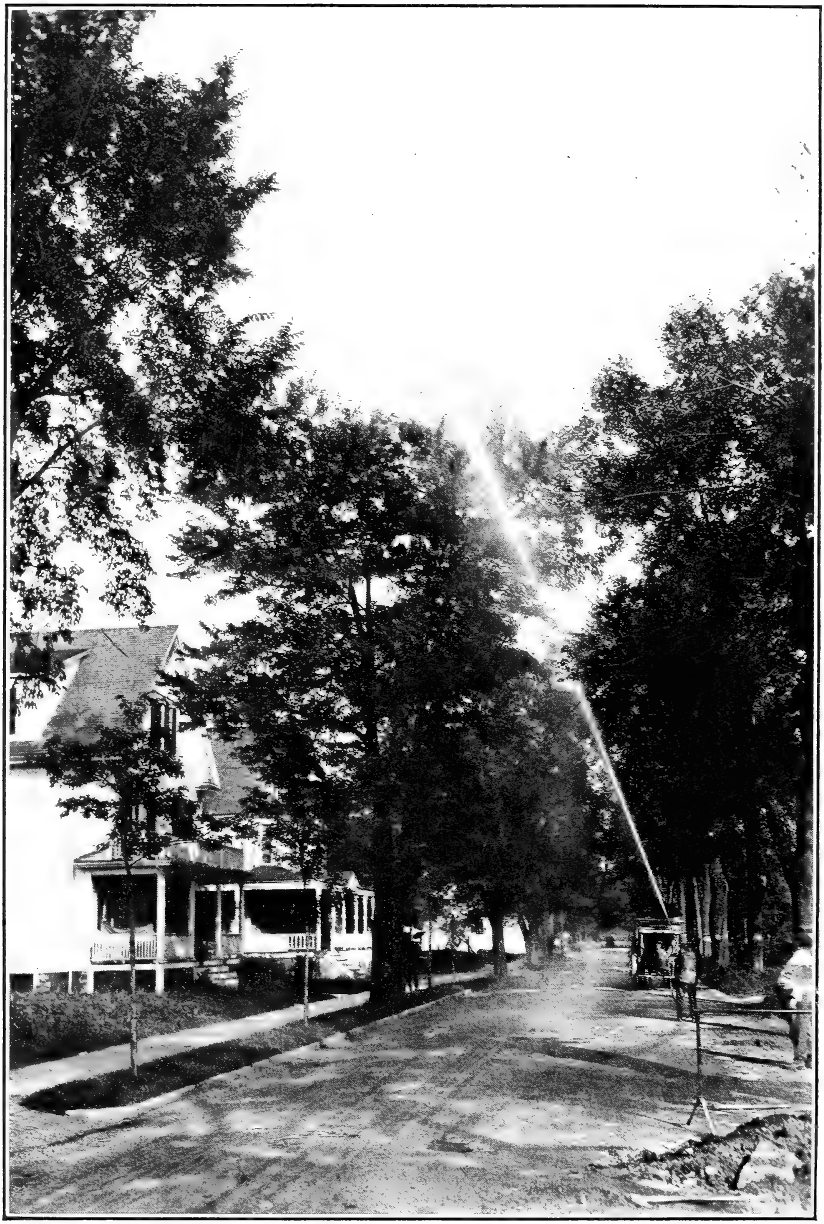
RESULTS OF TESTS FOR DISTRIBUTION OF POISON SPRAY.

Distribution of poison. Location of these plates is shown in Plate IX. (Original.)



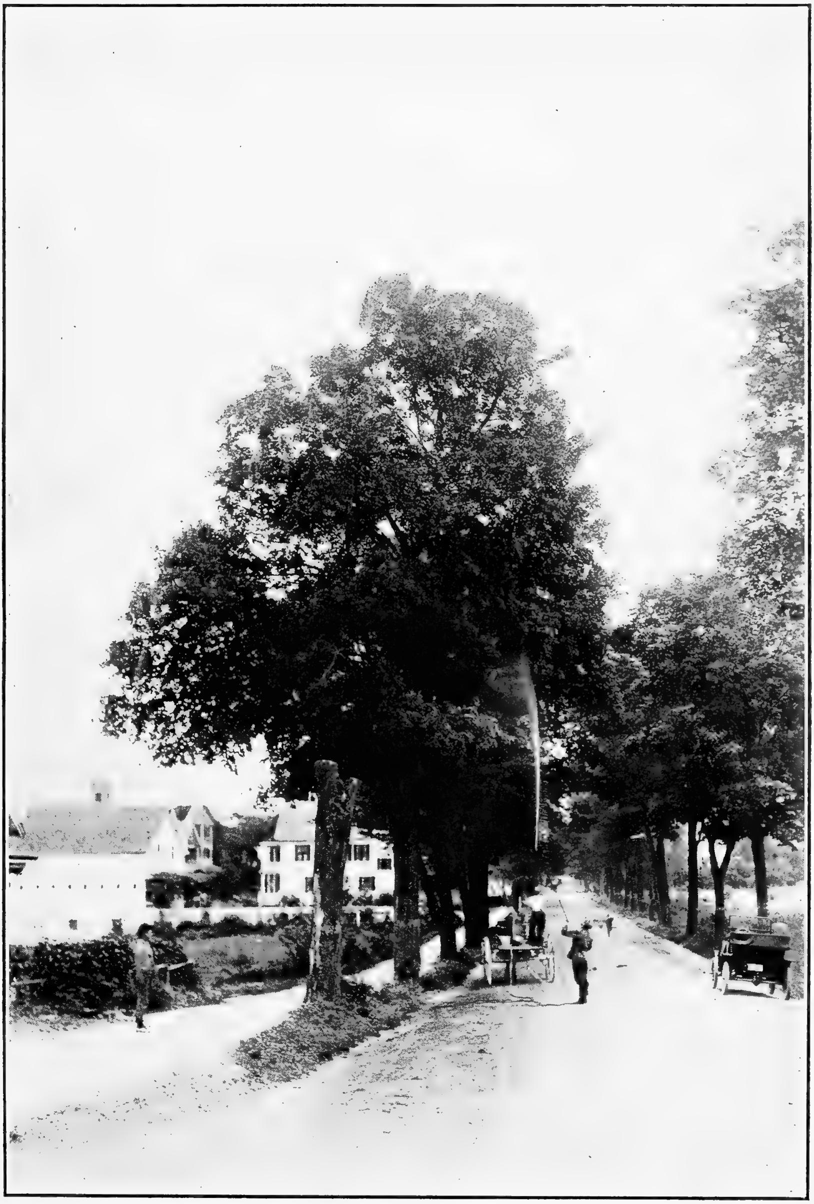
RESULTS OF TESTS FOR DISTRIBUTION OF POISON SPRAY.

Distribution of poison. Location of these plates is shown in Plate IX. (Original.)



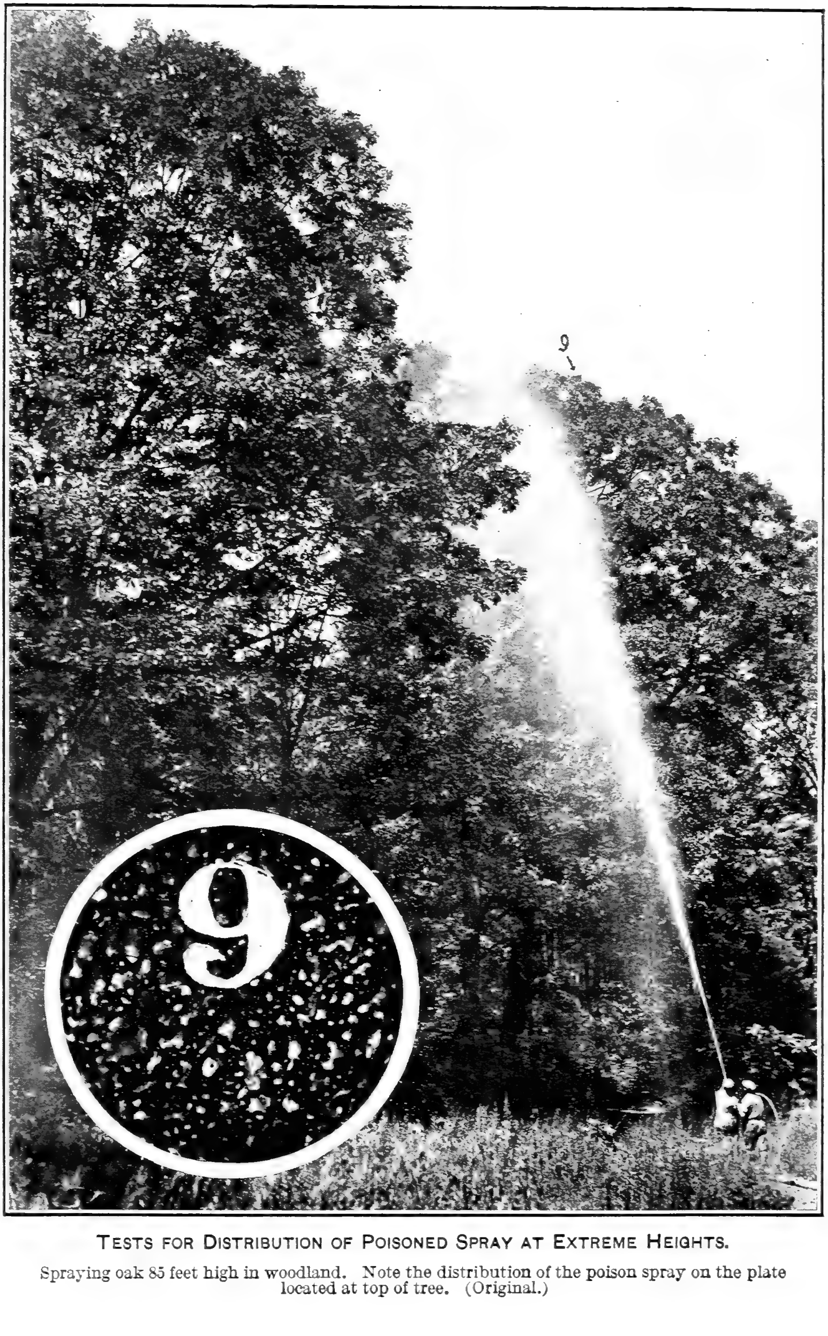
THE SOLID-STREAM SPRAYER IN OPERATION.

Spraying shade trees along the streets with solid stream. (Original.)



THE UNSATISFACTORY, OLD-TIME SPRAYING OPERATION WITH A HAND OUTFIT.

Spraying shade trees with hand outfit. These trees had to be climbed in order to treat the tops. (Original.)

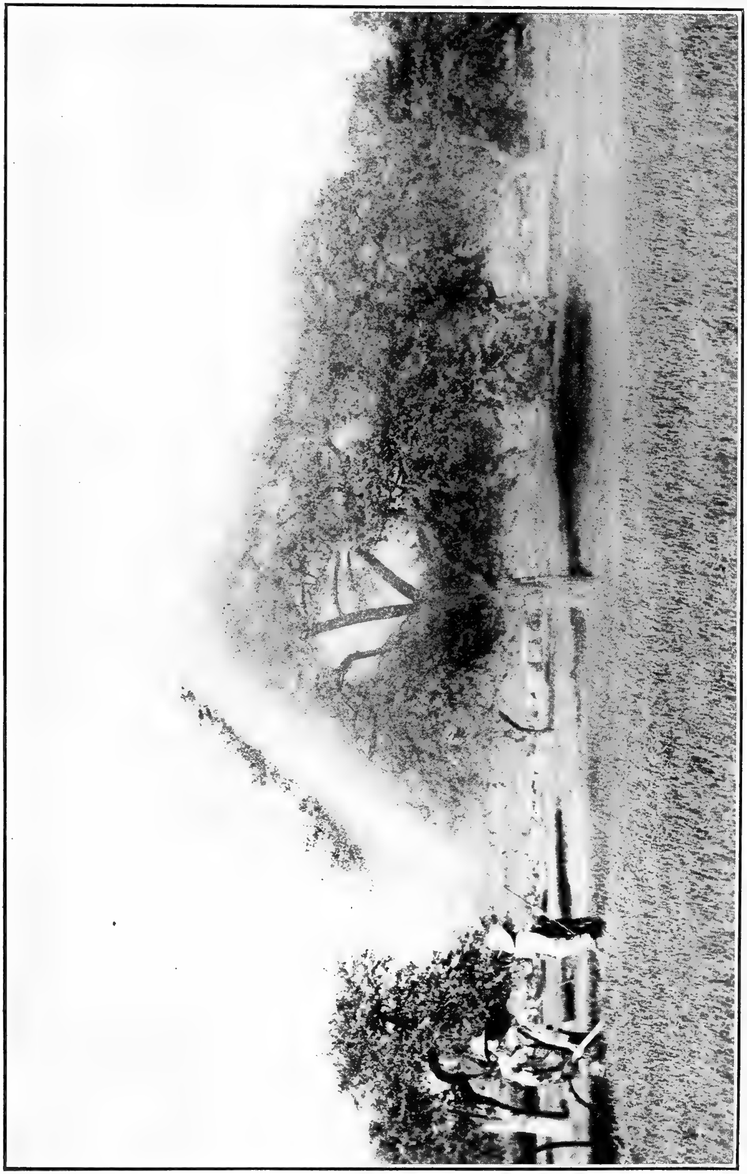


TESTS FOR DISTRIBUTION OF POISONED SPRAY AT EXTREME HEIGHTS.

Spraying oak 85 feet high in woodland. Note the distribution of the poison spray on the plate located at top of tree. (Original.)

ADAPTATION OF THE SPREADER IN SPRAYING OPERATIONS.

Spraying low growth, using spreader. (Original.)



ADAPTATION OF SPREADER TO ORCHARD-SPRAYING OPERATIONS.

Spraying orchard with solid stream, using spreader. (Original.)

to the leaves, and at the same time thoroughly treat the surrounding foliage. By using a spreader on the nozzles the lower foliage and undergrowth can be properly sprayed with much less damage or loss of solution than if the solid stream is applied. The essential thing in woodland spraying is to keep the nozzleman moving. Poison is sure to be wasted when stops are made for any length of time. Careful arrangements for water supply should be made in advance. Damming of brooks or digging holes in low ground to provide an accumulation of water will reduce the cost of spraying to a great extent. It sometimes becomes advisable in the spraying of large wooded areas to build temporary roads. This is often necessary from an economic standpoint, as the average wood road suitable for spraying machines can be built for 5 cents per square yard, and results in a great saving in the aggregate spraying cost. Especial care should be taken in the spraying of conifers, as the leaf area is very small and the stream must be broken into a fine mist in order to have the solution adhere.

WINTER CARE OF SPRAYING MACHINES AND EQUIPMENT.

Failure to take proper care of a spraying outfit is responsible for most of the difficulties and delays that result during the spraying season. This is particularly true in regard to the precautions that should be taken when the spraying season is over and the machine is laid up for the winter. If careful attention is not given to the apparatus at this time, many difficulties and delays are likely to result during the following season.

Each machine should be taken to a convenient water supply and clear water forced through the pump and hose until both are perfectly clean. The running gear should be thoroughly washed. After this has been done the hose should be laid away for the winter. Storing hose in coils should be avoided. The machine should be properly drained of water and all metal parts coated with heavy grease. Care should be taken that all valves and petcocks are open, and the plugs and packing in the pump should be removed for the winter to allow the latter to drain. After the water has been properly drained from the engine and the circulating pipes have been disconnected the engine should be started and run for a few minutes so as to force the water out of the pump and check valves into the water jacket of the engine, where the heat will cause it to evaporate. Care should be taken not to allow the engine to become overheated while being run under the above conditions. After this has been done the spark plugs should be removed and wrapped in oiled cloth to prevent rusting. After the spark plugs have been removed, pour a cupful of cylinder oil into each cylinder and turn the engine over a few times, so that the oil may be worked in around the piston rings. Cork stoppers should be placed

in the spark-plug holes to prevent moisture from entering the cylinders. The panels should be taken from both sides of the engine and all oil removed from crank case, after which the crank shaft and connecting rods should be coated with heavy grease. A few drops of light oil should be worked into all metal parts of the magneto bearing to prevent rusting.

SUMMARY.

The subject of spraying, either solid-stream or mist spray, should be given very careful consideration, as the importance of securing good results is imperative. If they are accomplished, much more interest and cooperation may be expected in the problem of controlling leaf-eating insects. It often happens that those responsible for the results do not give sufficient attention to important details until it is too late in the season to secure the best results. One should familiarize himself with every phase of spraying, so that he may be able to cope with all conditions. While there are still those at the present time who do not feel that solid-stream spraying with arsenate of lead can be as effective as that done with smaller machines and mist nozzles, all will concede that much good work has been accomplished in the gipsy-moth area in New England with solid-stream spraying. While the solid-stream method is confined almost entirely to shade-tree and forest spraying it has been used successfully in orchards (Pl. XVI). Solid-stream work is not necessarily confined to the highest-power machines, as good results may be obtained on a small scale with medium-power machines capable of delivering a solid stream of smaller size, and which at the same time may be easily converted to mist-spray work. This also applies to the larger machines.

The problem of fighting the gipsy moth and the brown-tail moth is of such magnitude and general economic importance that it would be impossible to do the necessary spraying in the infested area with mist spray and small machines. During part of many seasons the weather is not suitable for spraying, and when conditions are right a large amount of spraying must be accomplished in a short time. The work of several boring insects which have riddled our shade trees in the past few years has also made climbing of them much more hazardous, but this must be done if the mist spray is used. If climbing is resorted to, the expense is prohibitive, especially in wooded areas.

Many times the question is asked, "Why pursue other methods of fighting the gipsy moth and the brown-tail moth; why not confine it entirely to spraying?" There are several reasons; the nature and severity of the infestation must be taken into consideration, and the proximity and danger of spread to noninfested regions. If extermination is to be expected it would not be wise to confine all

efforts to spraying. If the infestation is severe and egg clusters are very numerous they should be treated with creosote prior to spraying. What is termed "rough creosoting" consists of treating the egg clusters, which can be easily reached in areas to be sprayed. In rare cases infested shade trees are located near buildings where it is impossible to spray without defacing the buildings to some extent. This can be avoided, however, if buildings are first wet with clear water. If the infestations are located in pasture lands, proper precaution should be exercised so that live stock will not be poisoned. Poison notices should be placed in conspicuous places in all locations where spraying is done.

From 800 to 1,000 tons of arsenate of lead and about 500 high-power solid-stream machines are being used each year in the New England States in fighting the gipsy moth. Thousands of acres of park and orchard trees and woodland in addition to approximately 20,000 miles of street trees are being sprayed. When spraying is properly done to control the gipsy moth, very little trouble is experienced with other leaf-eating insects.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

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The Gipsy Moth and the Brown-tail Moth, with Suggestions for their Control. (Farmers' Bulletin 564.)
Report on the Gipsy Moth Work in New England. (Department Bulletin 204.)
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